PROGRAM TITLE

Non-volatile, Rad-hard Random Access memory (RAM) on GaAs

TYPE OF REPORT

Preliminary Analysis

CONTRACT NUMBER

N00014-91-C-0019

CONTRACTOR

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SECURITY CLASSIFICATION

not classified

This short discussion summarizes the preliminary test results obtained with the first round of Sierra Monolithics RAM cells fabricated on GaAs by Honeywell.

RAM CELL DESIGN

The RAM cell consists of a Hall effect sensor in the form of a 20 micron N_- implanted square with ohmic connections at the four corners and a drive coil with four turns surrounding the Hall sensor. The layout of the RAM cell is shown in Fig. 1.

Att. #2

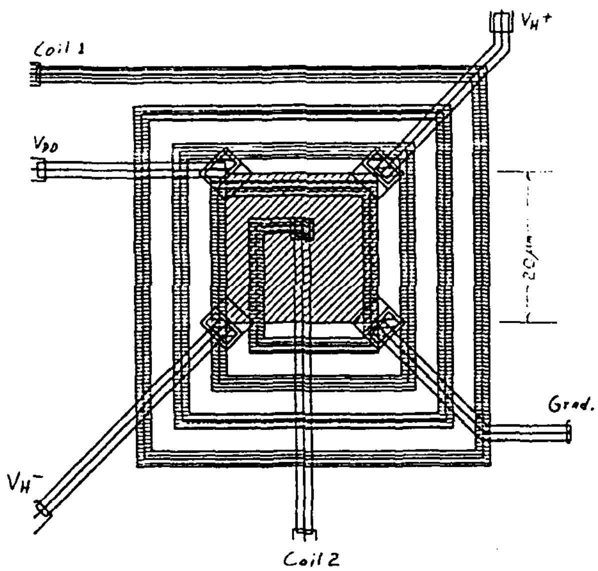

Figure 1. RAM cell layout.

The basic program plan was to evaluate the characteristics of the RAM cell and then implement the appropriate read and write supporting circuits around it to make a full memory element. Thus in the first round of fabrication no supporting circuitry was fabricated with the basic cell.

The RAM cell was fabricted at Honeywell's GaAs IC foundry which currently does not have a dedicated equipment to place the magnetic memory layer over the basic cell. Nevertheless this step is compatible with the rest of the GaAs IC process because it

would be the last step in the fabrication process.

Thus the plan was to place a separate magnetic layer over the RAM cell to complete the memory element. The separate magnetic layer can be for example a piece of magnetic recording tape, which has a coersivity of about 100 to 200 oersted and is in the right order of magnitude for this application.

RAM CELL DC CHARACTERISTICS

The DC characteristics of the RAM cell have been measured and they are listed below:

Hall element resistance	8 KΩ
Hall element output offset	<5 mV
Drive coil resistance	30 Ω
Hall sensitivity	.016 mV/V.Gauss

The RAM cell chip is mounted on a 12 pin TO-8 header with the cover unattached so that the magnetic film can be placed on top of the die.

RAM CELL MEMORY TEST CIRCUIT

A test circuit for the RAM cell has been designed and built to measure the memory response of the cell. The block diagram is shown in Fig. 2.

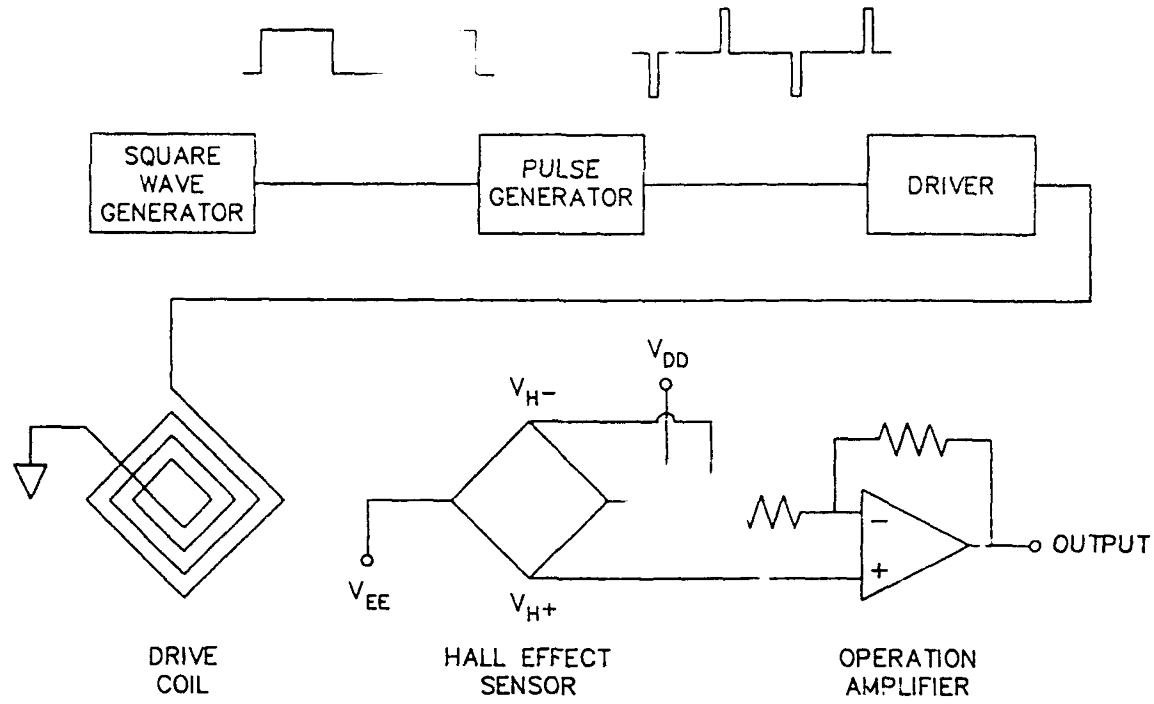

Figure 2. Block diagram of the RAM test circuit.

The test circuit has a square-wave generator with a frequency of about 0.7 Hz. This very low frequency is chosen becuase of the very long time constants associated with the trap states in GaAs. This rpoblem will be discussed in detail later. The falling and rising edges of the square wave are then used by a pulsing circuit to generate short positive and negative pulses, respectively as shown. The pulse width is around 260 microseconds. The pulse generator output is then fed to a driver circuit, which provide the low impedance drive for the coil on the RAM chip. The Hall sensor is biased by V_{dd} and V_{ee} which are ±2V. The two Hall sensor outputs are fed to an operational amplifier with a gain of 10.

TEST DATA

The memory cell is then tested with the test circuit which alternately writes a "+" and a "-" onto the cell.

Fig. 3 shows the scope traces of the square-wave signal (top trace) and the Hall sensor output through the op-amp (bottom trace) when no magnetic film is placed on top of the sensor.

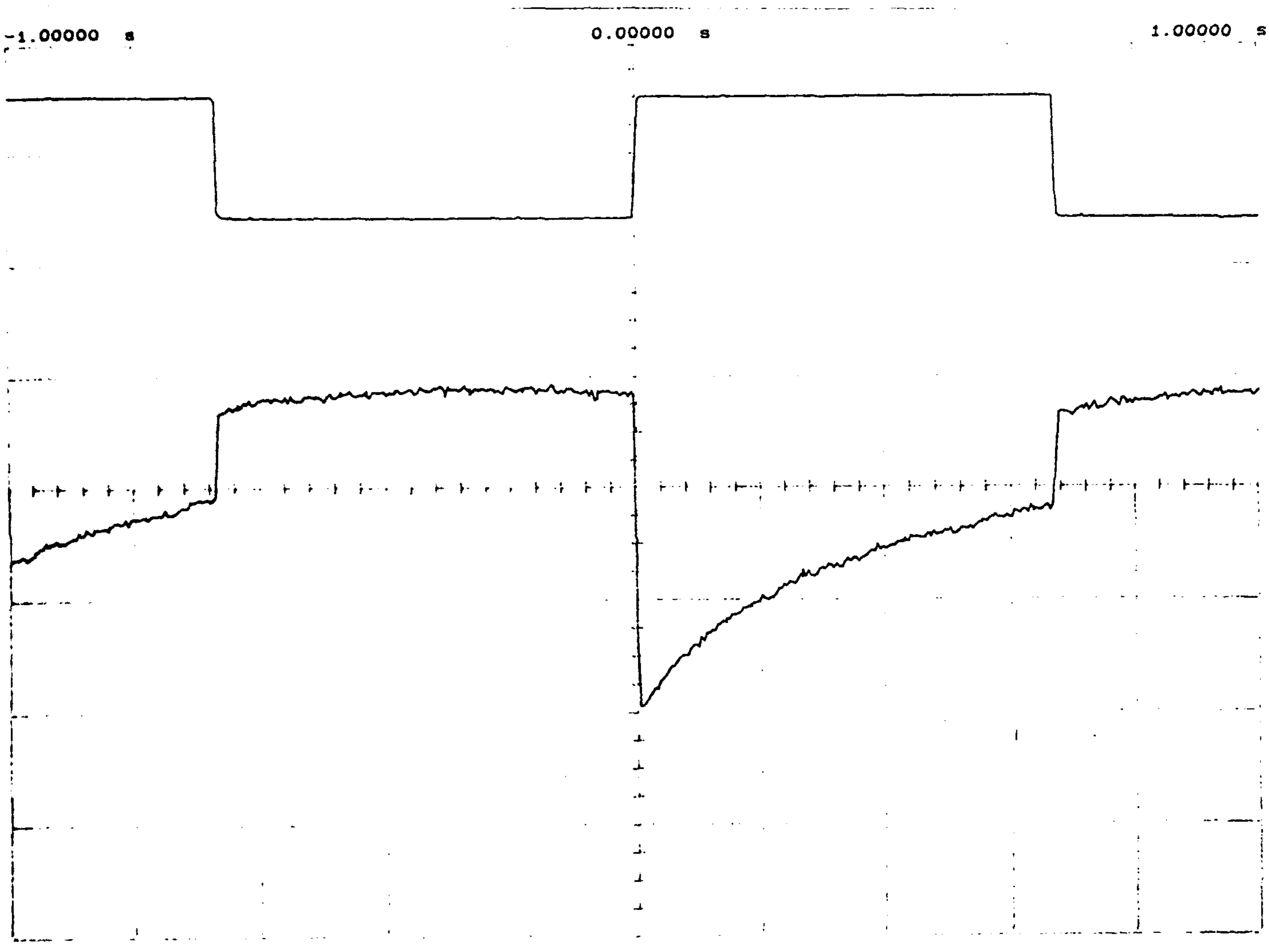

Figure 3. Measured data with no Magnetic film over hall sensor.

In this case when there is no magnetic film on top of the memory cell, one expects equal voltage level at the Hall sensor output (except at the falling and rising edges). This is not observed. Instead we see a memory effect.

Recall that at the falling edge of the square-wave, a short 260 microsecond current pulse writes a "+" while at the rising edge a "-" is written. Clearly a memory effect is present even in the absence of a magnetic film. This is believed to be due to the long-lived trap sites being excited by the drive signal possibly through electrostatic mechanisms. Fortunately, at least for the current design, the sense or polarity associated with this spurious memory mechanism is the same as that associated with the magnetic overlayer. Thus it enhances rather than interferes with the desired magnetic memory effects.

However, in order to measure the true memory effect of the magnetic layer, the relatively large spurious memory effect associated with the traps make it necessary to perform the measurement in a differential manner and look at the difference of the data between the case without the magnetic film and the case with the film.

The same data taken with the magnetic film over the Hall sensor is shown in Fig. 4

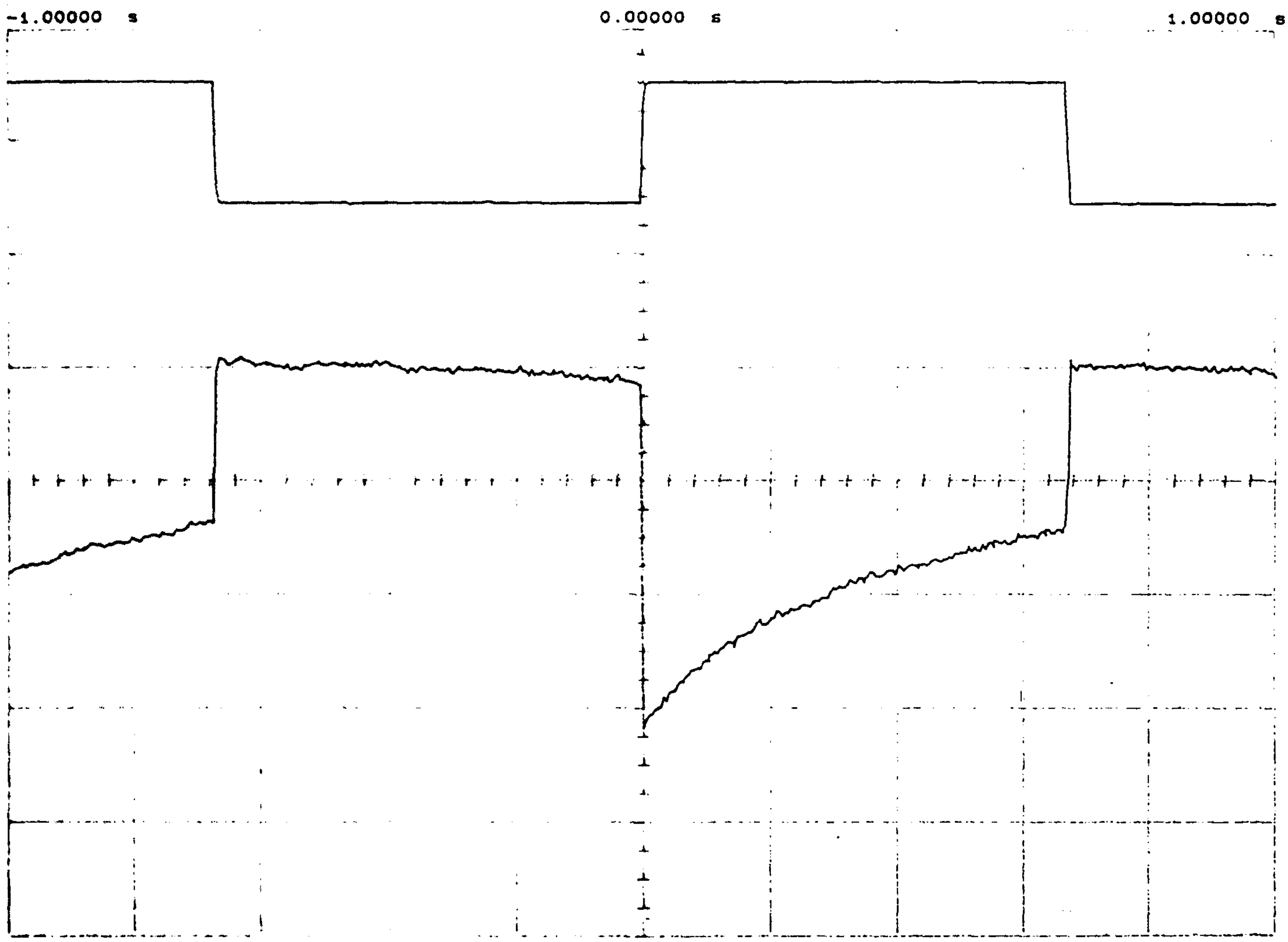

Figure 4. Measured data with magnetic film over the Hall sensor.

In order to compare the two figures, the data taken with the magnetic film is overlayed on top of the data taken without the magnetic film and is shown in Fig. 5 where the black line is with magnetic film and the gray line is without. The data with the magnetic film shows more swing and the difference between the back line and the gray line is the memory effect due to the magnetic film.

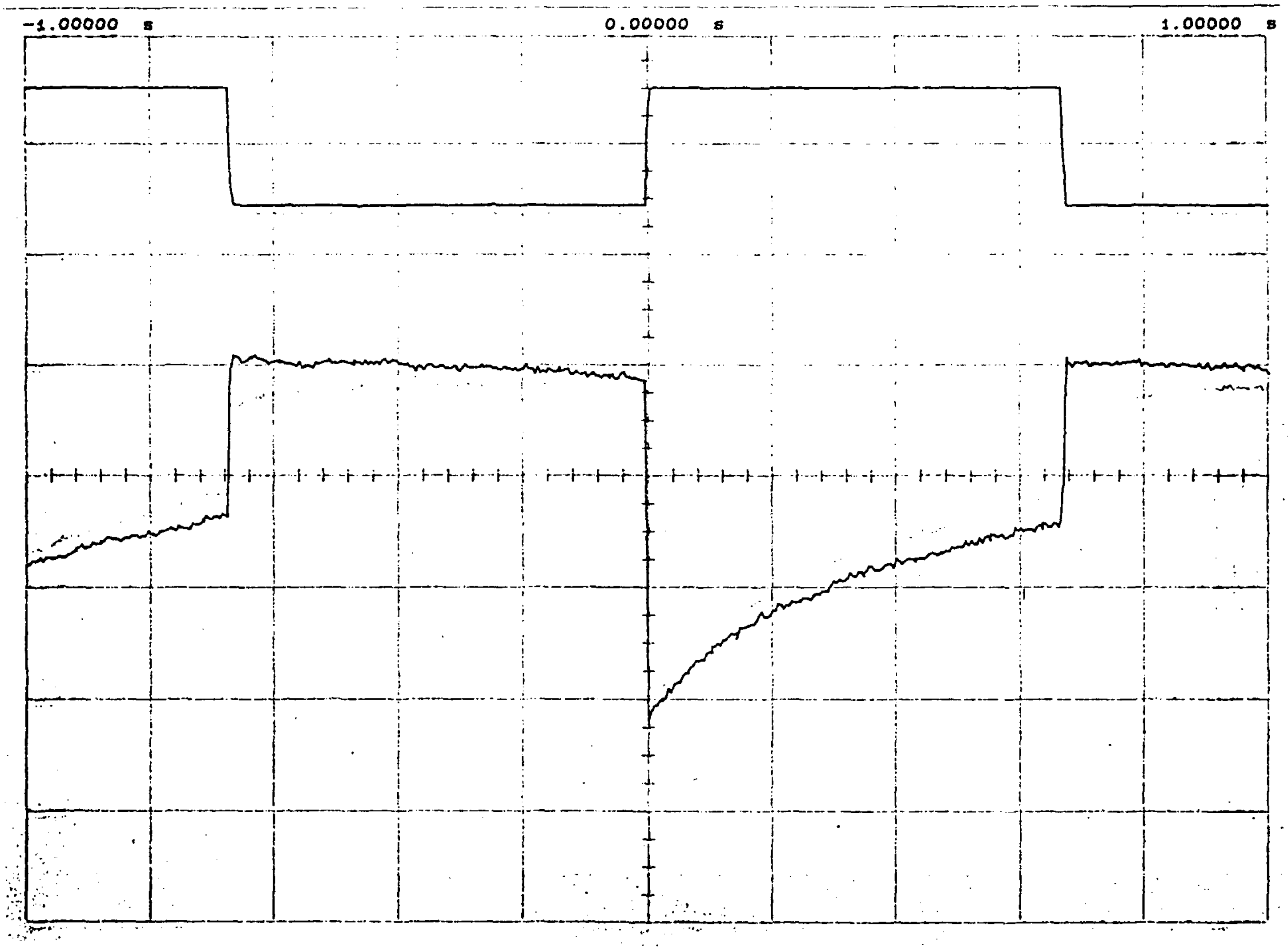

Figure 5. Overlay of data with and without magnetic film.

QUANTITATIVE DATA ANALYSIS

The scale on Fig. 5 is 20 mV/division. The difference signal has an amplitude about 4 mV which corresponds to .4 mV output at the Hall sensor. With a Hall sensitivity of .016 mV/V.Gauss, the field as seen by the Hall sensor is

$$B = [.4\text{mV}/4\text{V}]/[.016\text{mV/V.Gauss}] = 6.25 \text{ Gauss.}$$

The drive current is 200 mA with a magnetic path of approximately 100 microns. Thus the drive field is about

$$\begin{aligned} H &= 4\text{x}.2\text{A}/10^{-4}\ \text{m x } 4\pi \text{ x}10^{-3}\ \text{oe}/[\text{A/m}] \\ &= 100 \text{ oersted.} \end{aligned}$$

This field should result in a much larger remanent field than the observed 6.25 Gauss. One potential cause for this discrepancy is that the magnetic film material has a much larger coersivity than 100 oersted so that the film is not driven into saturation. This deficiency can be corrected by the use of a magnetic material with a lower coersive force.

SUMMARY

In summary we make the following observations:

1. The memory effect using a magnetic overlayer, a coil for write and a Hall sensor for non-destructive read (NDRO) has been established.

2. The spurious memory effect should be eliminated in the next round of fabrication by placing a ground potential gate on the Hall sensor, a positive bias on the substrate, and physical separation between the Hall sensor and the driving coil metalization. These steps would eliminate the back gating and the long lived trap problem.

3. By design any residual memory effects due to the traps can be made to provide the same polarity as the megnetic effects so they do not interfere with the desired signal.

4. Compensation or layout symetrizing techniques can be used to reduce the Hall sensor off-set to less than 1 mV.

5. A suitable magnetic material with a lower coersivity (<100 oe) can be used to achieve saturation and therefore a higher remanant field (>40 Gauss) thereby giving rise to a signal of greater than .4mV x 40 Gauss / 6.25 Gauss = 2.56 mV. Such a signal will then be greater than the Hall sensor off-set. As a result the state of the memory can be read by the polarity of the Hall sensor output.

6. Double layer coil can be implemented to reduce the required drive current to below 100 mA.